

Mesoscale Model Simulations of Coastal Fog

Christopher A. Davis
Mesoscale and Microscale Meteorology Division
National Center for Atmospheric Research
PO BOX 3000
Boulder CO 80307-3000
phone: 303-497-8990
fax: 303-497-8181
e-mail: cdavis@ucar.edu
Award #: N00014-96-0044
<http://www.mmm.ucar.edu/mm5/mm5-home.html>
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LONG TERM GOAL

We wish to understand the factors governing the formation of coastal fog, especially its horizontal variability and relationship of variations to flow interaction with coastal topography.

OBJECTIVE

We wish to obtain successful simulations of the onset, variability (on scales of tens of kilometers) and dissipation of coastal fog using a nonhydrostatic mesoscale model.

APPROACH

Using the Pennsylvania State University/National Center for Atmospheric Research Mesoscale Model version 5 (MM5v2), we conduct simulations of coastal fog events. MM5 has several options for parameterizing the planetary boundary layer (PBL). We have chosen to work with four PBL schemes in particular: Blackadar (Grell et. al, 1994), Gayno-Seaman (Gayno, 1994; adapted from Ballard et al, 1991), Burk-Thompson (Burk and Thompson, 1989), and MRF (Hong and Pan, 1996). Since the Gayno-Seaman scheme is newly implemented in MM5, and includes features not traditionally available in PBL schemes in MM5, we have been particularly interested in how this scheme compares with other schemes in simulating coastal fog.

To assess the ability of these PBL schemes to produce realistic and accurate simulations of coastal fog, we compare simulations (using the different PBL schemes) of coastal fog events to one another and to conventional observations and satellite imagery. Shallow model layers near the surface are needed with these simulations in order to represent the physical interactions between the surface and the atmosphere that occur on small scales in the vertical. High resolution in the horizontal is used to assess atmospheric interactions with terrain, and particularly the interactions of fog with terrain. Sensitivity tests are performed to further explore conditions important to the evolution of coastal fog.

WORK COMPLETED

Work has continued from last year's implementation and initial tests in MM5 of the Gayno-Seaman PBL scheme. This scheme is a higher-order PBL scheme, explicitly predicting turbulent kinetic energy (TKE). Another advantageous feature of this particular scheme for this study is its explicit treatment of fog formation as more gradual process that can occur in grid boxes that are as a whole subsaturated.

Several cases have been simulated with MM5, using a variety of PBL schemes. Most of these cases occurred off the New England coast. One particular case has been selected for more detailed experiments. Since the sea-surface temperature fields for that case seemed to be inadequate for the detailed simulations we planned to perform, we adjusted the sea-surface temperature field based on subjective interpretation of SST observations and IR satellite imagery.

Twenty-four hour simulations were performed with two-domain and three-domain model setups. The horizontal grid spacing of the grids in the three-domain simulations were 60, 20, and 6.6 km, respectively. These simulations used 38 model levels. The lowest level was situated at approximately 6 m AGL, with the next few levels at approximately 18, 33, and 50 m AGL. We determined the vertical resolution used in these simulations based on experiments in a 2d version of MM5. The warm-rain microphysics option was selected, but the liquid-water fields were initialized to zero. For subjective verification, surface and sounding reports and GOES-8 satellite imagery have been examined.

RESULTS

For the cases selected, there is some agreement in the simulations among the PBL schemes as to the general horizontal distribution of the fog (e.g. Fig. 1). This agreement is most pronounced earlier in the simulations, in the four to six hour timeframe. The general distribution in the simulations also bears some correspondence to satellite imagery of the fog (Fig. 2). Based on previous experience with simulating boundary-layer phenomena with the Blackadar scheme in MM5, this was somewhat unexpected. Since the main difference between the model configurations of these simulations and previous MM5 simulations is the vertical resolution, this result suggests that a key feature of any model setup expected to simulate coastal fog is high vertical resolution in the lowest model levels. A comparison run, using the Burk-Thompson scheme with more traditional vertical resolution in MM5 (lowest level at about 38 m, next levels at about 113, 228, and 421 m) produces cloud water much later in the simulation, and little cloud water over the ocean (Fig. 3). Further tests to find a lower-limit on the vertical resolution (i.e., maximum model layer depth), needed to represent coastal fog processes may be in order.

While there was some agreement as to the horizontal distribution of the fog, differences among the schemes appear in the timing, initiation mechanisms, liquid water content, and depth of fog layer. Particularly noticeable was the Burk-Thompson scheme, which maintained a more widespread fog much shallower than in the other three schemes. Also notable was the tendency for Gayno-Seaman to initiate fog over land at the coastline, where other schemes initiated fog over water. Further investigation is needed on this subject.

Further tests have confirmed that the Gayno-Seaman scheme appears to be slower to produce fog. The transfer of sensible heat from the surface-layer air to a colder sea-surface appears to be slower in Gayno-Seaman than in the other schemes. One interesting (and perhaps suspect) feature of the Gayno-Seaman simulations that merits further investigation is the pattern of surface sensible heat flux, particularly over land, which shows sensible heat flux from the atmosphere into the ground is maximized right at the coastlines. This results in more cooling near the coast, and makes the coastline a preferential location for fog formation.

IMPACTS/APPLICATIONS

Results from this study illustrate the importance of vertical resolution in a model expected to simulate fog processes. The handling of fog processes by the various PBL schemes will likely be a consideration for future forecast and simulation experiments.

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IN-HOUSE/OUT-OF-HOUSE RATIOS

0%/100%

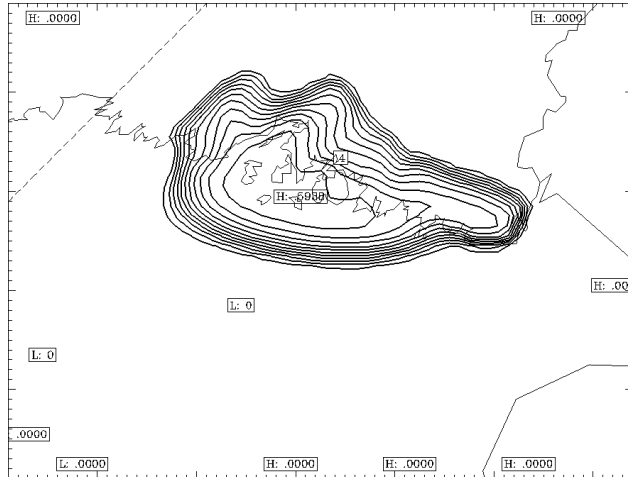


Figure 1a. Lowest sigma-level cloud water mixing ratio (g kg^{-1}) on 07 August 1998, at 0700 UTC, a)Gayno-Seaman PBL

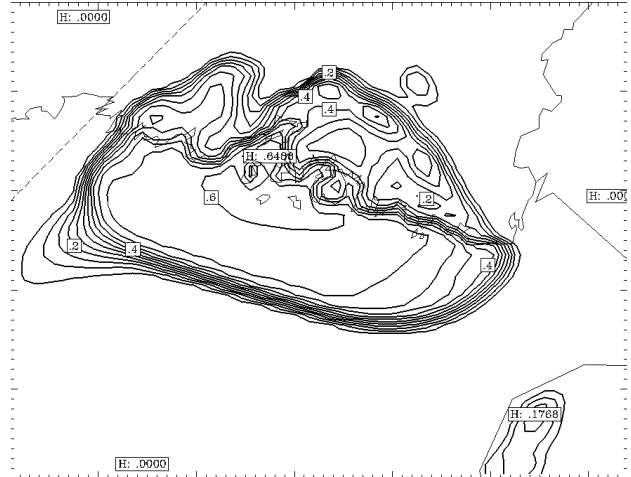


Figure 1b: MRF PBL

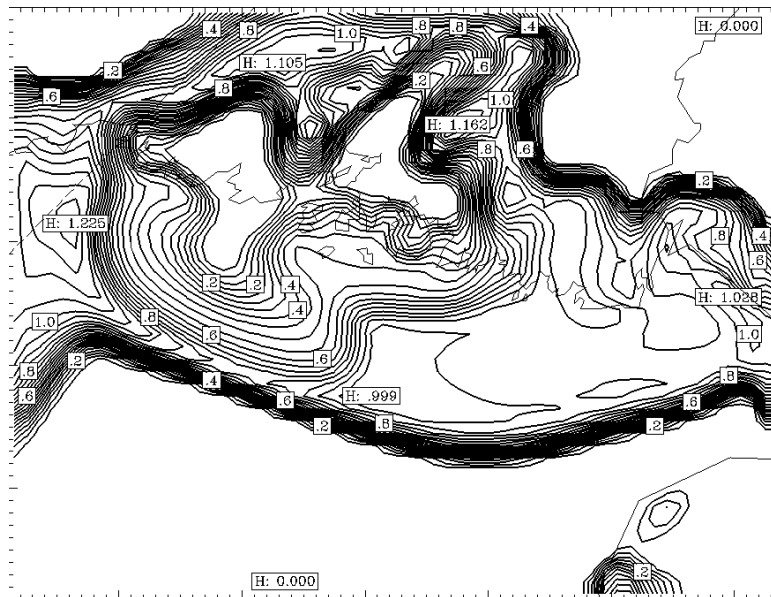


Figure 1c: Burk-Thompson PBL

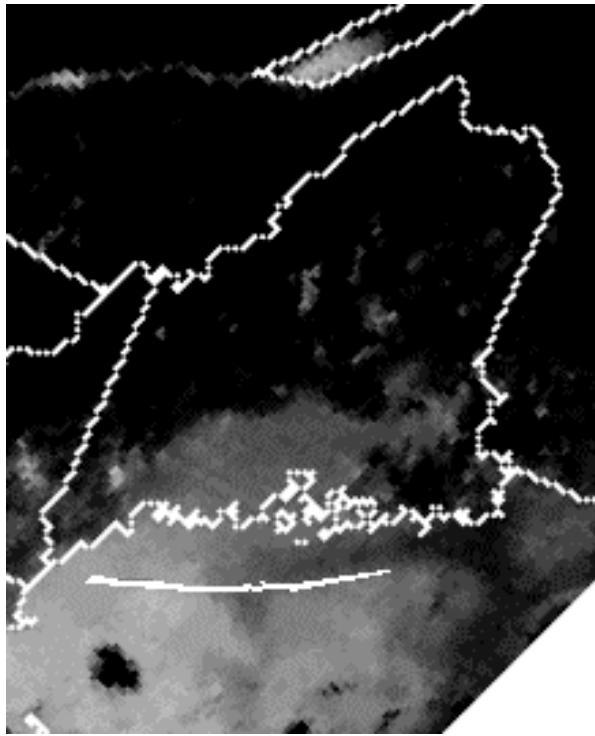


Fig. 2. IR-Channel satellite image for time corresponding to Fig. 1. The approximate seaward boundary of fog is indicated by the line just off the coast of Maine (more clearly determined by animation and later satellite images).

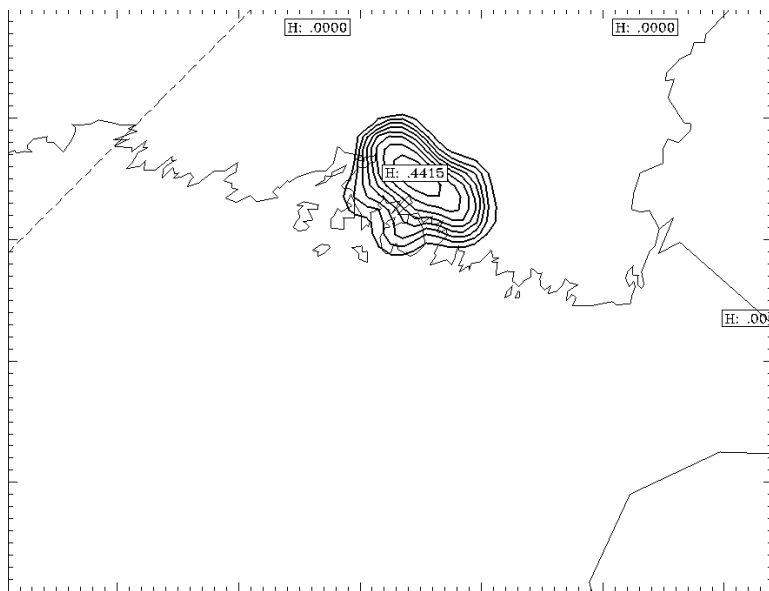


Fig. 3. Lowest sigma-level cloud water mixing ratio on 07 August 1998, at 0800 UTC, with low vertical resolution and the Burk-Thompson PBL.

